The Patent Office
Concept House
Cardiff Road
Newport
South Wales
NP10 8QQ

I, the undersigned, being an officer duly authorised in accordance with Section 74(1) and (4) of the Deregulation & Contracting Out Act 1994, to sign and issue certificates on behalf of the Comptroller-General, hereby certify that annexed hereto is a true copy of the documents as originally filed in connection with the patent application identified therein.

In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

In accordance with the rules, the words "public limited company" may be replaced by p.l.c., plc, P.L.C. or PLC.

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Signed

Dated 24 September 2003

Patents Form 1/77

Patents Act 1977
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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
Gwent NP10 8QQ

1.	Your reference	2002P15476 GB / R76 / CF / GD
2.	Patent application number *(The Patent Office will fill in this part)* 01 OCT 2002	0222692.6
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	ROKE MANOR RESEARCH LIMITED Old Salisbury Lane, Romsey Hampshire SO51 0ZN
	Patents ADP number *(if you know it)* 05615455006	
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	Autonomous Vehicle Guidance on or near Airports
5.	Name of your agent *(if you have one)*	
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	Siemens Plc Intellectual Property Department The Lodge, Roke Manor Romsey, Hampshire SO51 0ZN
	Patents ADP number *(if you know it)* 08472193001	
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filling of the or of each these earlier applications and *(if you know it)* the or each application number	Country / Priority application number *(if you know it)* / Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filling date of the earlier application	
8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer ,Yes' if: *a) any application named in part 3 is not an inventor,or*	Yes

IDNR: 7100 / V: 02-1.00 / B: Val

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b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

9. Enter the number of sheets for any of the following items you are filling with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	3
Claim*(s)*	0
Abstract	0
Drawing*(s)*	3

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translation of priority documents	
Statement of inventorship and right to grant a patent *(Patents Form 7/77)*	1
Request for preliminary examination and search *(Patents Form 9/77)*	
Request for substantive examination *(Patents Form 10/77)*	
Any other documents *(please specify)*	

11. I/We request the grant of a patent on the basis of this application

Signature

Date

Clive French
Intellectual Property Department

01.10.2002

12. Name and daytime telephone number of Person to contact in the United Kingdom

Clive French + 44 1794 83 3573

IDNR: 7100 / V: 02-1.00 / B: Val

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Patents Form 7/77

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Statement of inventorship and of right to grant of a patent

(See the notes on the back of this form)

The Patent Office

Cardiff Road
Newport
Gwent NP10 8QQ

1.	Your reference	2002P15476 GB / R76 / CF / GD
2.	Patent application number *(If you know it)*	01 OCT 2002 0222692.6
3.	Full name of the or of each applicant	ROKE MANOR RESEARCH LIMITED Old Salisbury Lane, Romsey Hampshire SO51 OZN
4.	Title of the invention	Autonomous Vehicle Guidance on or near Airports
5.	State how the applicant*(s)* derived the right from the inventor*(s)* to be granted a patent	By provisions of contract of service and Section 39(1) (a) and (b) of the Patent Act 1977.
6.	How many, if any, additional Patents Forms 7/77 are attached to this form? *(see note (c))*	None
7.		I/We believe that the person*(s)* named over the page *(and on any extra copies of this form)* is/are the inventor*(s)* of the invention which the above patent application relates to. Signature C French Date Clive French 01.10.2002 Intellectual Property Department
8.	Name and daytime telephone number of person to contact in the United Kingdom	Clive French + 44 1794 83 3573

Patents Form 7/77

Patent Acts 1977
(Rule 15)

7/77

Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

1)
SPRIGGS Timothy John
23 Island Close
Hayling Island PO11 0NJ

Patents ADP number *(if you know it)*: 07978745001

2)

Patents ADP number *(if you know it)*:

3)

Patents ADP number *(if you know it)*:

4)

Patents ADP number *(if you know it)*:

5)

Patents ADP number *(if you know it)*:

6)

Patents ADP number *(if you know it)*:

IDNR: 7105 / V: 02-1.00 / B:Val

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Autonomous Vehicle Guidance on or near Airports

The Problem

In our patent application GB 0127904.1 "Detection of Foreign Objects on Surfaces" it was observed that an autonomous vehicle on an airport would need to be constrained to operate on an airport within an area defined by an external means. Potential external means include rails, buried conductors, fencing or a precise navigation system. Near to a runway the rail and fence options, although providing positive restraint, are impractical and forbidden by regulations. One of the outstanding problems with the indirect methods is how to persuade the Safety Regulator that the vehicle is sufficiently constrained and will not, for example, wander onto the runway.

The present invention makes use of "existing" airport infrastructure, giving a solution that is cost-effective, and that should be acceptable to the Regulatory Authority. It is not limited to vehicles engaged in detecting foreign objects, e.g. it could easily be applied to the constraint of "airside" grass-cutting robots.

Background to the Solution

The concept of Satellite Navigation using, for example, GPS, is well known; what is probably less well known is that such systems are inadequate for use by commercial air traffic. Although the accuracy obtainable may be adequate for all but landing operations, the Integrity and Continuity of Service performance of these systems leaves a bit to be desired.

Augmentation systems are being developed to enable the use of satellite navigation for commercial air transport. The main systems currently in development are EGNOS (the European Geostationary Navigation Overlay Service), MSAS (MTSAT[1] Satellite-based Augmentation System) and the WAAS (Wide Area Augmentation Service). All of these systems depend on additional, geostationary, satellites to transmit integrity, correction and status data. Augmentation systems need not be space-based; there are also air- and ground-based augmentation systems (ABAS & GBAS) proposed. What follows concentrates on the GBAS, as illustrated in Figure 1. A full function GBAS will allow so-called Category III landings to be made with satellite navigation, i.e. it replaces the current Instrument Landing Systems (ILS) for "blind landings".

One of the main differences between the ILS and the GBAS is the ubiquity of the latter on and around the airport. ILS works by sending narrow radio frequency beams off airport in defined directions; they guide in the aeroplanes. GBAS in contrast, uses a VHF Data Link to send integrity information and corrections for use by satellite navigation receivers in radio line-of-sight. Aircraft equipped, and certificated, to use these augmentations need not make the long straight beam-following approaches of ILS; they could, for example, come in on curved paths alternatively from either side of the extended runway centre line; this would increase safety by reducing the time for which aircraft are relatively close together.

The navigation corrections and integrity data are derived from an array of receivers at precisely known positions on or near to the airport. Pseudolites may also be used in some situations where insufficient navigation satellites are continuously in view.[2]

[1] MTSAT is the Japanese Multi-Function Transport Satellite.

[2] Pseudolites, pronounced 'pseudo-lights', are not satellites but provide valid satellite navigation signals.

Description of the Invention

This invention addresses the problem of autonomous vehicles on the airport needing to be constrained only to work in particular areas; typical applications could be debris-monitoring or grass-cutting robots. Legally, such constraint has to be deemed acceptable by the Safety Regulator and cannot involve construction of anything adjacent to the runway that is not also an "aid to air navigation". Although plenty of 'low profile' items are allowed next to taxiways, we want a solution for the whole of the movement area. What is proposed is to employ a GBAS that is intended for use in "blind landing" of aircraft as a high integrity source of navigation data that can be compared with pre-defined, or operator defined, areas of permitted operation within the vehicle's guidance system. The concept can also be used, albeit with less precision in position, using an alternative high integrity navigation service. For example, that from another augmentation system, such as the space-based EGNOS.

The basis requirement is to constrain a vehicle to operate within a particular area for a specific purpose. This then requires the area to be defined for the vehicle and a means for the vehicle to 'know' its position within the area. The latter is straightforward prior art; to take advantage of the high integrity navigation service the robot needs to be equipped with a suitable receiver comprising a navigation receiver, a data receiver and a Navigation Processor that estimates the position based upon the measurements made and the supplementary data received.

The purpose of the vehicle operation dictates strategies for the modus operandi during use; this current description is restricted to the definition of the boundaries. Strategies will also have to be developed, depending on purpose and place of operation, defining what the vehicle is to do should it find itself outside its allowed area.

The area definition can be achieved in a number of ways, depending on application and what type of equipment is already available to the user. It could, for example, be predefined by the operating authority and 'down-loaded' to the vehicle by direct or wireless means; alternatively it could be entered manually to the vehicle, or the vehicle could be taught by being taken to the place and shown the boundary. This could either be by taking it along the edges or just to the points that define the corners. In the latter case, unless the area is a triangle, corners are not sufficient, the vehicle also requires to know which of the corners are connected directly to each other via edges. Well-surveyed areas lend themselves to remote definition methods, whereas 'arbitrary' deployments would be easier with the teaching method.

Note that although it has to be connected, the operating area does not have to have a single boundary, i.e. it can have holes in it. It could also be a track, i.e. the vehicle is constrained to operate along a defined path rather than within a defined area.

A number of user-friendly means of entering polygonal shape information into computing systems is known in the prior art, for example using a pointing device to draw a representation of the required area onto a map representing the airport displayed on a screen or printed onto a tablet. These techniques are used for example in air traffic control systems to define restricted airspace. A ground movement control system on an airport could be extended to manage the autonomous vehicles and used to define their constraint areas.

Whatever is chosen, the process itself is independent of the means of implementation and is represented by the diagram of Figure 2. In that diagram the rectangles represent the 'actors', i.e. the people or machines external to the vehicle that interact with it; circles represent processes, i.e. how information is changed in the system; and directed lines represent flows of information between

processes and other processes or actors. The arrow on the information flows indicates where the net flow is going; it does not imply that there is no acknowledgement or other protocol. A line with an arrow on each end represents a dialogue of information. The dotted line on the diagram encompasses a sub-set of the processes that can be carried on the vehicle. This line is dotted as it is not a firm boundary; some, or all, of the area defining processes may also be included on the vehicle at the discretion of the implementer or, for example, the constraint validation may be performed off-vehicle.

Once the vehicle has been given its constraints, it may operate within them to whatever strategy has been defined for the purpose. For example a system sensing debris and foreign objects on the runway would patrol up and down the length of the runway, but offset from the edge; a grass cutter may also go up and down, but it may alternatively 'spiral in' to the centre of its area. This may, for example, be implemented as a rule-based system that tailors the strategy to the constraints to provide a plan of operations for the vehicle, or it may apply the constraints 'on the fly'. In either case the vehicle requires to have a path management system or equivalent that directs its motion by providing instructions to the traction control based upon position estimates from a navigation processor, the strategy and the constraints. (See Figure 3)

Although the term vehicle has been used in this description the principles clearly apply to any roving equipment, be it on wheels, legs or other means of mobility. It should also be noted that there may be required some override function so that, for example, the ground movement controller could move the equipment away from the runways if an emergency landing is in progress. A strategy for this would be to define a "muster point" to which the vehicles must go on receipt and validation of the override signal.

It has been observed that the areas near the runways are clear of obstructions other than aids to navigation, it should be noted that this is not the case in other areas, e.g. near the edge of a taxiway there may be low fences. There may also be small pits containing, e.g. power distribution equipment. The vehicle must avoid all these hazards, but this need not necessarily be by use of the constraint areas described; the vehicle may also carry diverse means of obstacle avoidance, for example a vision system as described in our patent GB 2218507 or GB 2246261. Vehicles may also operate in concert with others as per GB 2231220 for example, scanning for debris from both sides of a run way at once to improve detection probabilities.

It would be advantageous in most cases for there to be a 'global' area in which the vehicle could be required to operate on a particular occasion being defined using the foregoing process. In the simplest case the 'global' area could be made up of a mosaic of smaller areas, not necessarily connected, and one of these tiles is selected for the current operation. Selection could be for example by placing the vehicle within the desired tile and, on initialisation, it would automatically recognise in which tile it is located and start operations.

John Spriggs

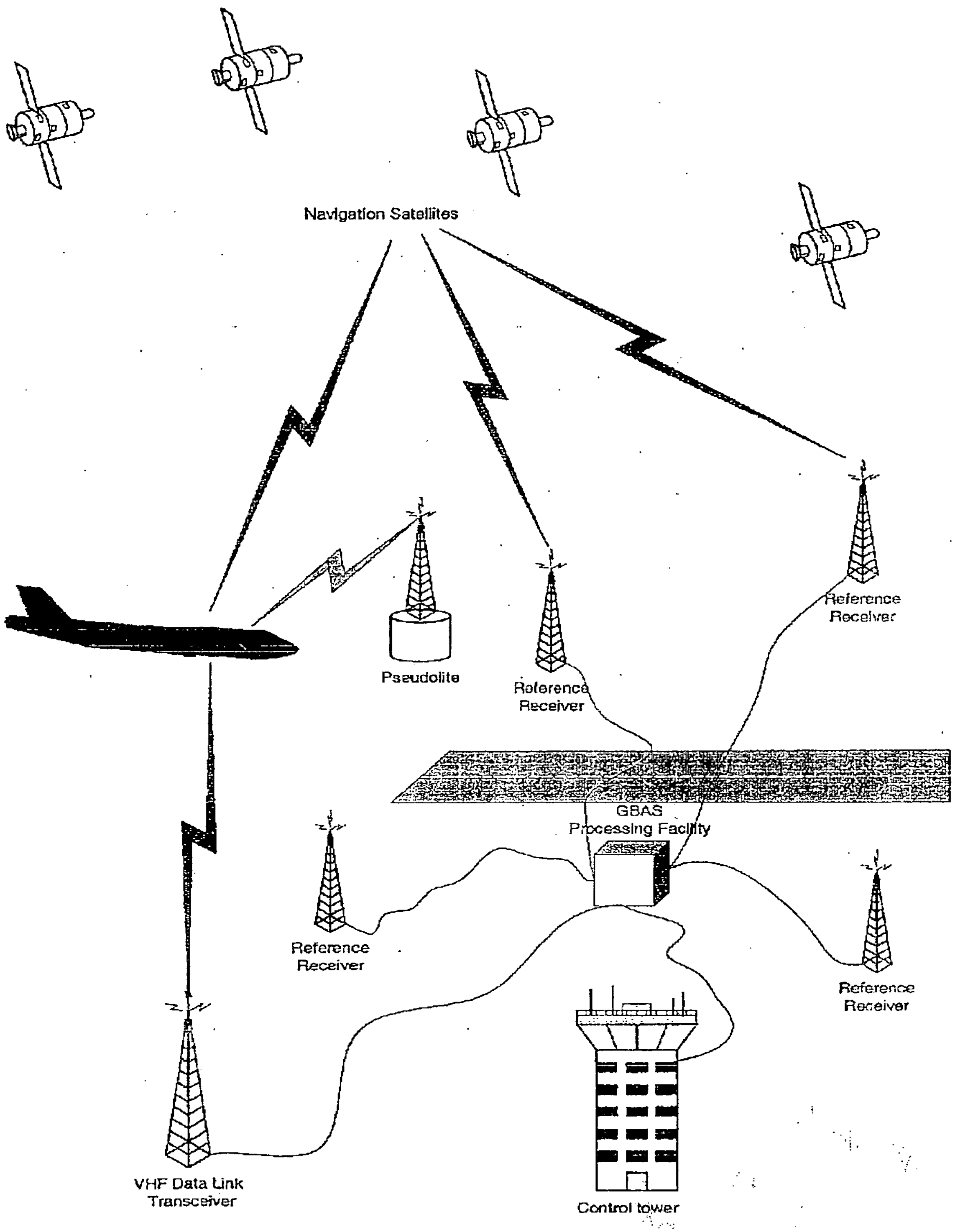

Figure 1 ~ Prior Art:
A Ground Based Augmentation System Architecture

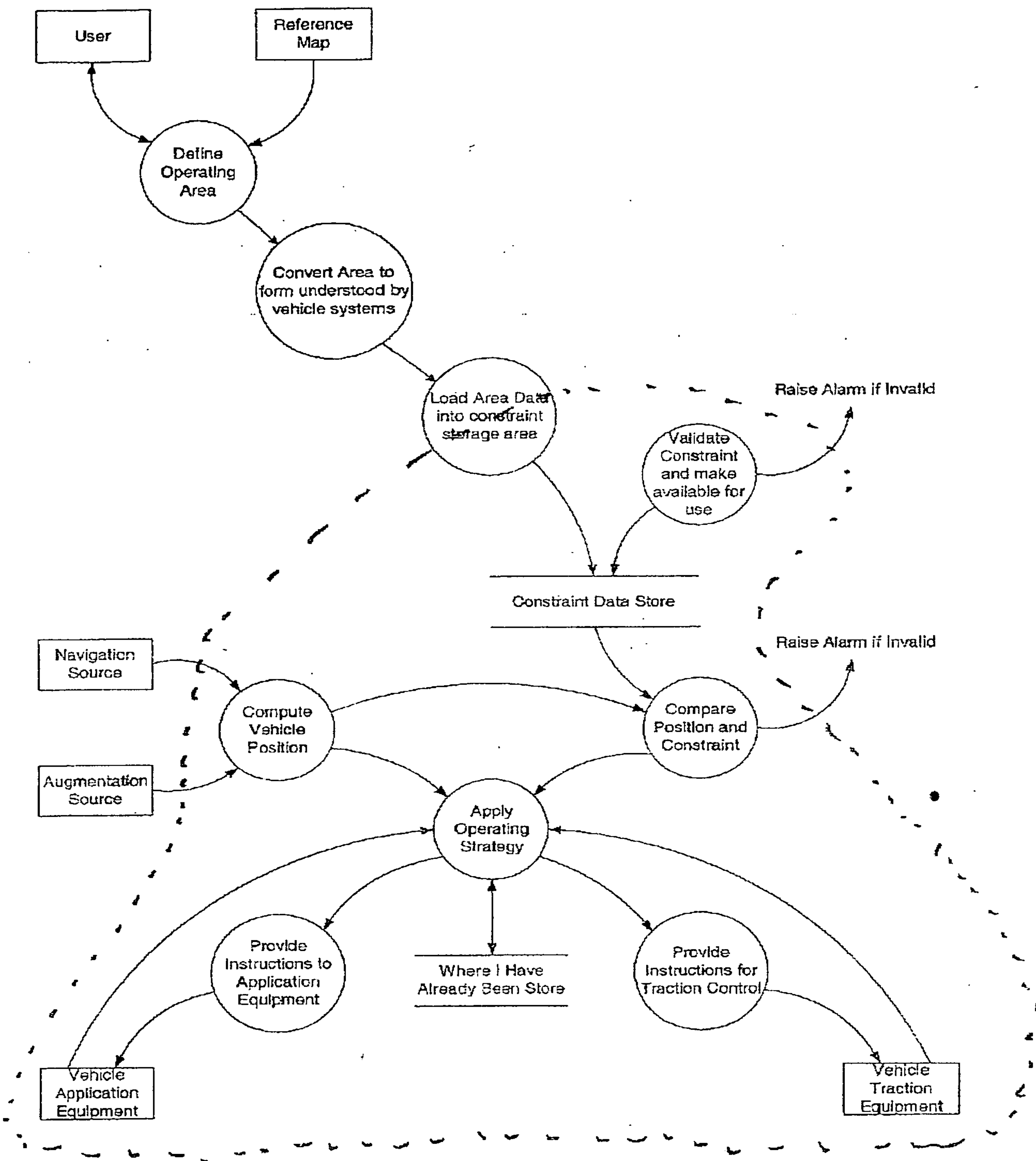

Figure 2 – High-level Process Flow

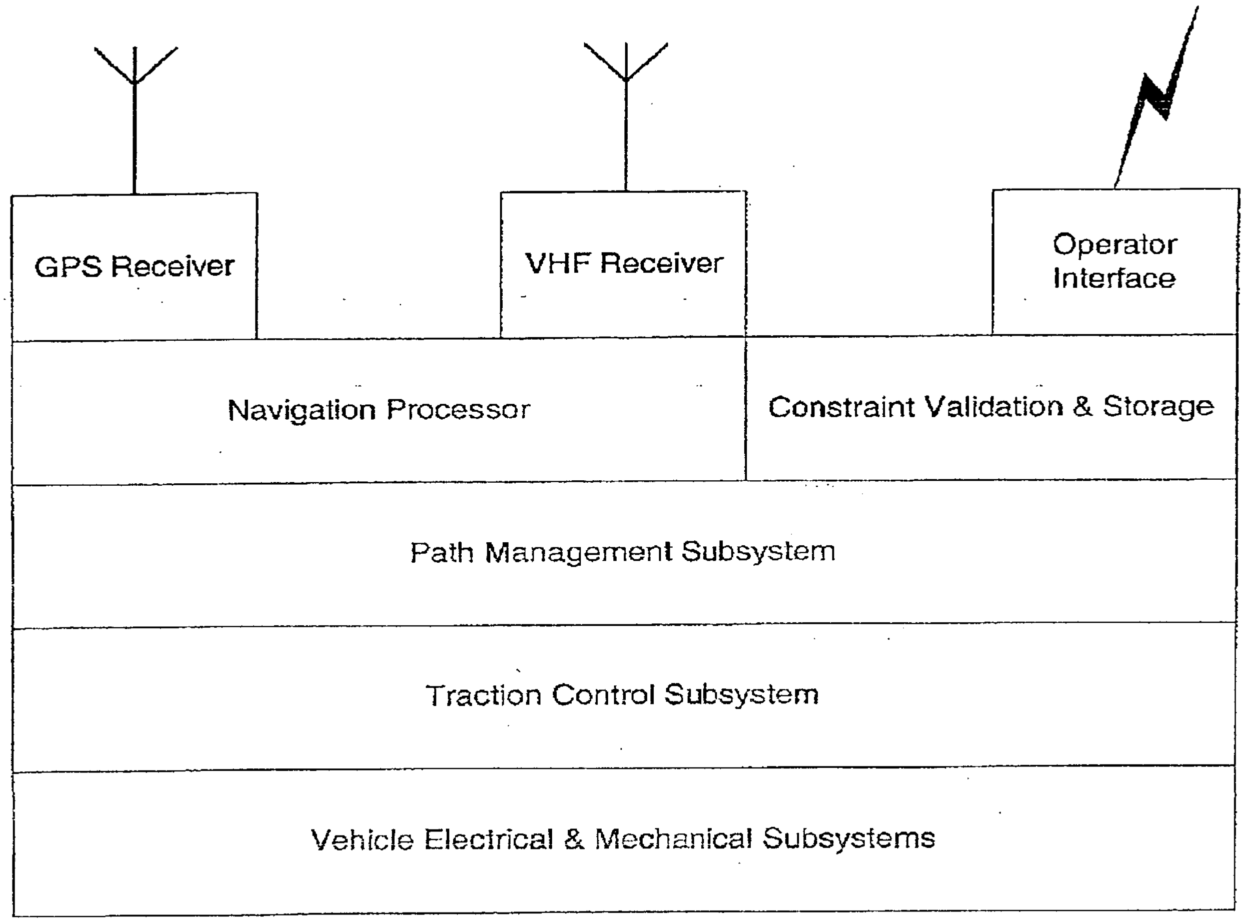

Figure 3 ~ Functional Block Diagram of Vehicle Subsystems